



**FATIGUE LIFE BEHAVIOUR OF FIBERGLASS  
REINFORCED COMPOSITES SUBJECTED TO CONSTANT  
AND VARIABLE AMPLITUDE LOADINGS**

**ROY HANSON ANAK JIMIT**

**MASTER OF SCIENCE IN MECHANICAL ENGINEERING**

**2018**



**Faculty of Mechanical Engineering**

**FATIGUE LIFE BEHAVIOUR OF FIBERGLASS  
REINFORCED COMPOSITES SUBJECTED TO CONSTANT AND  
VARIABLE AMPLITUDE LOADINGS**

**Roy Hanson Anak Jimit**

**Master of Science in Mechanical Engineering**

**2018**

**FATIGUE LIFE BEHAVIOUR OF FIBERGLASS REINFORCED COMPOSITES  
SUBJECTED TO CONSTANT AND VARIABLE AMPLITUDE LOADINGS**

**ROY HANSON ANAK JIMIT**

**A thesis submitted  
in fulfilment of the requirement for the degree of Master of Science  
in Mechanical Engineering**

**Faculty of Mechanical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2018**

## **DECLARATION**

I declare that this thesis entitled “Fatigue Life Behaviour of Fiberglass Reinforced Composites Subjected to Constant and Variable Amplitude Loadings” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Roy Hanson Anak Jimit

Date : .....

## **APPROVAL**

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in term of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature : .....

Supervisor Name : Dr. Kamarul Ariffin Bin Zakaria

Date : .....

## **DEDICATION**

To my beloved family especially my wife; Jacquelyn Liang, my parents; Mr Jimit Maying  
and Mrs Beremas Gani, and my siblings; Nancy Jimit and David Jimit.

## ABSTRACT

This study focuses on the variable amplitude loadings effect on fatigue life behaviour of Fiberglass-reinforced composite (FGRC). Unidirectional fiberglass-reinforced composite were used as subjects of this study due to their wide application in automotive and engineering components. The manufacturing some of automotive parts are made from fiberglass including the interior or exterior panels, dashboard components, seats, spoilers, sills panel and body structures. The study of fatigue life under variable amplitude loadings (VAL) is an important subject as most of engineering components are subject to stresses which vary with time. Fatigue failure usually occurred without warning. Therefore, the needs of more predictive tools and understanding on the integrity of this material could help to produce a more reliable engineering material in the future. The main objective of this study is to investigate the effect of overloads (OL) and underloads (UL) toward the fatigue life behaviour of the FGRC test coupon of different orientation which are  $[0/90]^\circ$  and  $[\pm 45]^\circ$  orientations and chopped strand mat (CSM). Firstly, a static finite element analysis was performed to determine the most critical area of the FGRC test coupon. Next, the critical stress value was recorded from the tensile test on the test coupon according to the standard in ASTM D3039. Tensile test is carried out to determine the mechanical properties of the FGRC. The results showed that the Ultimate Tensile Stress (UTS) of FGRC is the highest in  $[0/90]^\circ$  orientations compared to  $[\pm 45]^\circ$  orientation and CSM. After that the fatigue tests were carried out at room temperature in accordance to the ASTM D3479 for both Constant Amplitude Loadings (CAL) and Variable Amplitude Loadings (VAL). Secondly, the CAL fatigue test is carried out for all the orientations including CSM. Results showed  $[0/90]^\circ$  orientations have the highest fatigue life cycle. Thirdly, OL and UL effects were generated from the CAL fatigue test results. Results showed that UL effect deteriorate the fatigue life behaviour of FGRC from 1.4% to 14% decrement from the actual value when being compared to result in CAL due to acceleration effect in fatigue crack growth rate while the effect of OL increase the fatigue life behaviour of FGRC by minimum 5% from the actual value due to retardation effect in the fatigue crack growth rate.

## ABSTRAK

*Kajian ini memfokuskan kesan pembebanan pelbagai amplitud ke atas perilaku hayat lesu komposit gentian kaca bertetulang (FGRC). Komposit gentian kaca bertetulang digunakan sebagai bahan kajian ini kerana penggunaannya yang meluas dalam komponen automotif dan kejuruteraan. Antara bahagian automotif yang diperbuat daripada gentian kaca termasuk yang digunakan dalam pembuatan panel dalaman atau luaran, komponen papan pemuka, tempat duduk, panel ceruk dan struktur badan. Pengkajian hayat lesu di bawah pembebanan pelbagai amplitud merupakan subjek yang penting kerana sebahagian besar komponen kejuruteraan dikenakan tegasan yang berubah-ubah dengan masa. Kegagalan lesu biasanya berlaku tanpa amaran. Oleh itu, perlunya lebih banyak kaedah ramalan dan pemahaman tentang integriti bahan ini akan membantu menghasilkan bahan kejuruteraan yang lebih dipercayai dan mapan pada masa hadapan. Objektif utama kajian ini adalah untuk mengkaji kesan beban lebih (OL) dan beban kurang (UL) ke atas perilaku hayat lesu sesebuah sampel ujian FGRC bagi orientasi yang berbeza iaitu orientasi  $[0/90]^\circ$  dan  $[\pm 45]^\circ$  dan gentian yang dicincang (CSM). Pertama, analisis unsur terhingga secara statik dilakukan untuk menentukan kawasan paling kritikal pada kupon ujian tersebut. Seterusnya, nilai tegasan kritikal dicatatkan dari ujian tegangan pada kupon ujian mengikut piawaian dalam ASTM D3039. Ujian tegangan dilakukan untuk menentukan sifat mekanik FGRC. Keputusan menunjukkan bahawa kekuatan tegangan muktamad (UTS) FGRC adalah yang tertinggi dalam orientasi  $[0/90]$  berbanding dengan orientasi  $[\pm 45]^\circ$  dan CSM. Selepas itu, ujian lesu dilakukan pada suhu bilik mengikut ASTM D3479 untuk kedua-dua pembebanan amplitud-malar (CAL) dan pembebanan pelbagai amplitud (VAL). Kedua, ujikaji lesu CAL dijalankan untuk semua orientasi termasuk CSM. Keputusan menunjukkan orientasi  $[0/90]$  mempunyai kitaran hayat lesu tertinggi. Ketiga, kesan OL dan UL dijana daripada keputusan ujikaji lesu CAL. Keputusan menunjukkan kesan UL terhadap perilaku jangka hayat lesu merosot daripada 1.4% hingga 14% daripada nilai sebenar apabila dibandingkan dengan keputusan CAL disebabkan kesan percepatan terhadap kadar retak lesu manakala kesan OL terhadap perilaku jangka hayat lesu meningkat sekurang-kurangnya 5% daripada nilai sebenar disebabkan kesan rencatan terhadap kadar retak lesu..*



## **ACKNOWLEDGEMENTS**

First and foremost, I would like to give my highest gratitude to the Almighty God for His blessings that I have now completed my Master of Science in Mechanical Engineering. Special thanks also dedicated to my main supervisor Dr Kamarul Ariffin Bin Zakaria and Dr Omar Bin Bapokutty as my co-supervisor for their supervision during the duration of my research. They have helped and guided me very well regarding useful informations and research techniques in order for me to complete this research project.

I would also like to express my deepest gratitude to the Ministry of Higher Education (MOHE) Malaysia, for funding my research project under RAGS research grant and the authority of Universiti Teknikal Malaysia Melaka (UTeM), especially to the Faculty of Mechanical Engineering for providing useful and conducive facilities for me to conduct my research works.

At last, I would like to extend my special thanks to my beloved wife, beloved parents, beloved siblings and my all my peers for their encouragement, love and motivations throughout my whole journey. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

## TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vi
LIST OF FIGURES	viii
LIST OF APPENDICES	xi
LIST OF SYMBOLS	xii
LIST OF ABBREVIATIONS	xiii
LIST OF PUBLICATIONS	xv
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Background of Study	1
1.2 Problem Statement	4
1.3 Objectives	6
1.4 Scopes of Research	6
1.5 Hypothesis	7
1.6 Thesis Structure	7
<b>2. LITERATURE REVIEW</b>	<b>10</b>
2.1 Introduction	10
2.2 Fatigue Failure Mechanism	10
2.3 Fatigue Loading	14
2.3.1 Constant Amplitude Loading	14
2.3.2 Variable Amplitude Loading	16
2.4 Fatigue Life Analysis	21
2.5 Composite Material	24
2.5.1 Reinforcement Phase	25
2.5.2 Matrix Phase	25
2.6 Fabrication of Composite	28
2.7 Factors Affecting Fatigue Behaviour	29
2.8 Application and Advantages of Fiber Reinforced Composite Polymer	31
2.9 Finite Element Method (FEM)	32
2.10 Summary	36
<b>3. MATERIALS AND METHODOLOGY</b>	<b>38</b>
3.1 Introduction	38
3.2 Finite Element Model of the Composite	40
3.2.1 Designing and Modeling the Specimen	41
3.2.2 Define Material Properties	41

3.2.3	Define the Boundary Condition and Load	43
3.2.4	Meshing	44
3.2.5	Job Analysis	46
3.3	Fatigue Life Prediction of Composite Model	46
3.4	Fabrication of Composites Laminate	49
3.4.1	Material Selection	50
3.4.2	Manufacturing Process	51
3.5	Void Content	56
3.6	Sample Preparation for Mechanical Testing	58
3.6.1	Tensile Test	58
3.6.2	CAL Fatigue Test	61
3.6.3	VAL Fatigue Test	65
3.7	Summary	67
<b>4.</b>	<b>RESULT AND DISCUSSION</b>	<b>68</b>
4.1	Introduction	68
4.2	Fatigue Life Prediction of Composite Using Finite Element Analysis	69
4.2.1	Stress State Distribution of Composite Model	70
4.2.2	Life Prediction of Composite Model	72
4.3	Mechanical Properties of Fiberglass Reinforced Composite	75
4.4	Fatigue Life Behaviour of FGRC Subjected to Constant Amplitude Loading	83
4.5	Fatigue Life Behaviour of FGRC Subjected to Variable Amplitude Loading	92
4.5.1	Effect of OL Toward Fatigue Life Behaviour of FGRC	93
4.5.2	Effect of UL Toward Fatigue Life Behaviour of FGRC	102
<b>5.</b>	<b>CONCLUSION AND RECOMMENDATION</b>	<b>110</b>
5.1	Conclusion	110
5.2	Contribution to Knowledge	111
5.3	Recommendation for Future Studies	112
	<b>REFERENCES</b>	<b>114</b>
	<b>APPENDICES</b>	<b>131</b>

## LIST OF TABLES

TABLE	TITLE	PAGE
3.1	Material Properties of Composite Model E-Glass Fiber	42
3.2	Fiber Glass Composition	50
3.3	Mechanical Properties of Fiber Glass and Polyester Resin	50
3.4	Measured Density of Composite Panel	57
3.5	Void Content of Different Composite Orientation	58
3.6	CAL Fatigue Setting for Different Types of Composite Specimens	62
3.7	OL and UL Setting Based on 65 % UTS for [0/90°] Orientation	66
3.8	OL and UL Setting Based on 65 % UTS for [±45°] Orientation	66
3.9	OL and UL Setting Based on 65 % UTS for CSM	67
4.1	Comparison of the Stress Value for Experiment and FEA	72
4.2	Number of Cycle to Failure for Fiberglass Reinforced Composite [0/90°] and [±45°] Orientation	74
4.3	Mechanical Properties of FGRC	77
4.4	UTS Value for FGRC Obtained from Experimental and Reference	78
4.5	E Value for FGRC Obtained from Experimental and Reference	79
4.6	Comparison of Trend for CSM and [0/90°] Orientation	80
4.7	UTS Value for CSM Obtained from Experimental and Reference	81
4.8	Number of Cycle to Failure of FGRC at [0/90°] Orientation	83
4.9	Number of Cycle to Failure of FGRC at [±45°] Orientation	84
4.10	Number of Cycle to Failure of FGRC for CSM	84
4.11	Fatigue Strength Coefficient and Basquin's Exponent of FGRC at [0/90°] Orientation Obtained from the Experimental and Reference	87

4.12	Fatigue Strength Coefficient and Basquin's Exponent of FGRC at $[\pm 45^\circ]$ Orientation Obtained from the Experimental and Reference	88
4.13	Fatigue Strength Coefficient and Basquin's Exponent of FGRC for CSM Obtained from the Experimental and Reference	89
4.14	Number of Cycle to Failure for Both Experiment and Simulation	90
4.15	Number of Cycle to Failure of FGRC at $[0/90^\circ]$ Orientation Subjected to Different OL Ratio	93
4.16	Number of Cycle to Failure of FGRC at $[\pm 45^\circ]$ Orientation Subjected to Different OL Ratio	94
4.17	Number of cycle to failure of FGRC for CSM Subjected to Different OL Ratio	94
4.18	Number of Cycle to Failure of FGRC at $[0/90^\circ]$ Orientation Subjected to Different UL Ratio	102
4.19	Number of Cycle to Failure of FGRC at $[\pm 45^\circ]$ Orientation Subjected to Different UL Ratio	103
4.20	Number of cycle to failure of FGRC for CSM Subjected to Different UL Ratio	103

## LIST OF FIGURES

<b>FIGURE</b>	<b>TITLE</b>	<b>PAGE</b>
1.1	Thesis Flow Structure	9
2.1	The Flow of Damages Occurred During Fatigue Failure in Composite	13
2.2	Three Failing Regions with Different Damage Mechanics of Unidirectional Fiber Composite	13
2.3	Classification of Fatigue Loading Condition	14
2.4	The Constant Amplitude Loading	16
2.5	Spectrum Loading with Overload and Underload Cycle	17
2.6	Load Parameters for a Simple Loading Scheme	18
2.7	Schematic of Delayed Retardation of Crack Growth Following Single OL	19
2.8	Crack Retardation in Fatigue Loading of Single OL	19
2.9	Semi-Log Scaled S-N Curve	23
2.10	The Structure Composition of Composite	24
2.11	Comparison Structure of Thermoplastics and Thermoset Presented Polyester Resin is the Best Choice	27
2.12	Hand Lay-up Method	29
2.13	Stress Distribution of Composite WTB under Maximum Fatigue Load	33
2.14	Finite Element Model of Turbine Blade Showing Loads and Boundary Conditions	33
2.15	Fatigue Assessment Using Design Life Software	34

2.16	Stress Contour of Static Strength Analysis	35
2.17	Fatigue Life Contour of Frame	36
3.1	Chronology of the Overall Study	39
3.2	Flow Chart for FEA	40
3.3	Dimension of Composite Specimen Modeled in ABAQUS	41
3.4	Laminate Thickness and Orientation for FEA Model	43
3.5	BC 1 ENCASTRE for Fiberglass Composite Model	44
3.6	BC 2 Displacement/Rotation for Fiberglass Composite Model	44
3.7	Load Configuration for Fiberglass Composite Model	45
3.8	Meshing Configuration for Fiberglass Composite Model	45
3.9	FEA Based Fatigue Life Prediction Interface	46
3.10	Time Series Generation Input for Simulation	47
3.11	Material Properties Generation for The Simulation	48
3.12	Load Mapping Based on Time Series for the Simulation	48
3.13	Process Flow of Fabrication Composite Laminate	49
3.14	Fiber Glass Cut into Required Size of 30 cm x 30 cm	51
3.15	The Mould Use for Fabrication	52
3.16	Unidirectional Fiber Glass is Weighed Individually	53
3.17	Resin is Weighed Using Digital Weighing Balance	54
3.18	CSM after Curing Process for 48 Hours in Room Temperature	56
3.19	Universal Testing Machine Instron 8872	59
3.20	Standard Tensile Test Specimen Dimensions as Per ASTM D3039	59
3.21	Extensometer is Fix on the Composite Sample During Tensile Test	60
3.22	Fracture Specimen after Tensile Test	61
3.23	The Display for Position and Load Setting in CAL Fatigue Test	63
3.24	Setup Display for the Setting of Mean Stress as a Function of Set Point in CAL Fatigue Test	64
3.25	Setup Display for the Setting of Load Amplitude and Frequency for CAL Fatigue Test	64
3.26	Overload or Underload Setting for VAL Fatigue Test	65
4.1	Schematic Diagram of Fatigue Life Estimation	70
4.2	Stress State Distribution of Composite Element of (a) [0/90°]	71

	Orientation and (b) $[\pm 45^\circ]$ Orientation	
4.3	FE Based Fatigue Life Prediction for Fiberglass Reinforced Composite at (a) $[0/90^\circ]$ Orientation and (b) $[\pm 45^\circ]$ Orientation	74
4.4	Comparison of the Prediction of Number of Cycles to Failure for $[0/90^\circ]$ and $[\pm 45^\circ]$ Orientations	75
4.5	The Stress versus Strain of Fiberglass Composite (a) $[0/90^\circ]$ Orientation, (b) $[\pm 45^\circ]$ Orientation and (c) CSM	76
4.6	Schematic Illustration of (a) Continuous and Aligned, (b) Discontinuous and Aligned and (c) Discontinuous and Randomly Oriented Fiber Reinforced Composites	82
4.7	Comparison of the Number of Cycles to Failure for the Different FGRC Sample	85
4.8	The Correlation of Fatigue Life between the Experiment and Simulation for $[0/90^\circ]$ Orientation	91
4.9	The correlation of fatigue life between the experiment and simulation for $[\pm 45^\circ]$ orientation	91
4.10	Comparison Number of Cycle to Failure for Different OL Ratio of : (a) $[0/90]^\circ$ , (b) $[\pm 45]^\circ$ and (c) CSM	96
4.11	Three Stages of Delayed Retardation of Crack Growth Rate	98
4.12	The Trend Effect of OL Ratio Toward the Number of Cycle to Failure: (a) $[0/90]^\circ$ , (b) $[\pm 45]^\circ$ and (c) CSM	100
4.13	Crack Growth Delay after Two Overloads Cycles as Affected by the Number of Cycles between the Overloads	101
4.14	Comparison Number of Cycle to Failure for Different UL Ratio of : (a) $[0/90]^\circ$ , (b) $[\pm 45]^\circ$ and (c) CSM	105
4.15	The trend effect of UL ratio toward the number of cycle to failure: (a) $[0/90]^\circ$ , (b) $[\pm 45]^\circ$ and (c) CSM	109



## **LIST OF APPENDICES**

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A	ASTM D2734 Standard Test Methods for Void Content of Reinforced Plastics	131
B	ASTM D3039 Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials	134
C	ASTM D3479 Standard Test Method for Tension-Tension Fatigue of Polymer Matrix Composite Materials	144
D	ASTM D5687 Standard Test Methods for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation	149

## LIST OF SYMBOLS

$\sigma_a$	-	Stress amplitude
$\sigma_r$	-	Stress range
$\sigma_{max}$	-	Stress maximum
$\sigma_{min}$	-	Stress minimum
$R$	-	Stress ratio
$N_D$	-	Number of delay cycle
$N_{D1}$	-	Real number of delay cycle
$a_D$	-	Delay distance
$\sigma_f$	-	Fatigue strength coefficient
$2Nf$	-	Sum of the reverse cycle
$b$	-	Basquin's exponent
$E_1$	-	Longitudinal modulus
$E_2$	-	Transverse modulus
$V_{12}$	-	Major Poisson's ratio
$G_{12}$	-	X-Y in-plane modulus
$G_{13}$	-	X-Z in-plane modulus
$G_{23}$	-	Y-Z in-plane modulus
$FV_f$	-	Fiber volume fraction
$\rho_f$	-	Fiber density
$\rho_m$	-	Matrix density
$T_d$	-	Theoretical density
$FW_f$	-	Fiber weight fraction
$V\%$	-	Void content
$M_d$	-	Measured density
$E$	-	Modulus of elasticity

$\varepsilon_{ult}$	-	Ultimate tensile strain
$N_f$	-	Number of cycle to failure

## LIST OF ABBREVIATIONS

ASTM	-	American Standard Testing Method
CAL	-	Constant Amplitude Loading
CGMC	-	Carbon and Graphite Matrix Composite
CMC	-	Ceramic Matrix Composite
CSM	-	Chopped Strand Mat
EU	-	European Union
FCG	-	Fatigue Crack Growth
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
FGRC	-	Fiberglass Reinforced Composite
FRC	-	Fiber Reinforced Composite
FRP	-	Fiber Reinforced Polymer
HDT	-	Heat Deflection Temperature
MMC	-	Metal Matrix Composite
OL	-	Overload
OLR	-	Over Load Ratio

PMC	-	Polymer Matrix Composite
RTM	-	Resin Transfer Molding
S-N	-	Stress-Life
UL	-	Underload
ULR	-	Under Load Ratio
UTS	-	Ultimate Tensile Strength
VAL	-	Variable Amplitude Loading
WHO	-	World Health Organization

## LIST OF PUBLICATIONS

### Journals

- 1     R. H. Jimit, K. A. Zakaria, O. Bapokutty and S. D. Malingam, 2018. *Tensile and fatigue behaviour of glass fiber reinforced polyester composites*. International Journal of Engineering and Technology (IJET), 7(3.17), pp. 25-27.
- 2     K. A. Zakaria, R.H. Jimit, S.N.S. Ramli, A.A. Azizi, O. Bapokutty and M. B. Ali, 2016. *Study on Fatigue life and fracture behaviour of fiberglass-reinforced composites*. Journal of Mechanical Engineering and Science (JMES), 10(3), pp. 2300-2310.
- 3     R. H. Jimit, K. A. Zakaria, O. Bapokutty and M. B. Ali. *Fatigue life behaviour of fiberglass-reinforced composites subjected to underloading*. Journals of Advanced Manufacturing Technology (JAMT). [Submitted]

## Conferences Attended

- 1     R. H. Jimit, K. A. Zakaria, O. Bapokutty and M. B. Ali. *Fatigue life behaviour of fiberglass-reinforced composites subjected to underloading*. 5<sup>th</sup> International Conference and Exhibition on Sustainable Energy and Advanced Material (ICE-SEAM 2017), Melaka, 16-19 OCTOBER 2017.
- 2     R. H. Jimit, K. A. Zakaria, O. Bapokutty and S. D. Malingam. *Effect of orientation on fatigue life behaviour of fiberglass reinforced composites*. 4<sup>th</sup> International Conference on Recent Advances in Automotive Engineering and Mobility Research (ReCAR 2017), Bangi-Putrajaya, 8-10 August 2017.
- 3     R. H. Jimit, K.A. Zakaria and O. Bapokutty. *Influence of fiber orientation on mechanical properties of fiberglass reinforced composite*. Proceedings of Mechanical Engineering Research Day 2017 (MERD'17), Melaka, 30 March 2017.
- 4     R. H. Jimit, K.A. Zakaria and O. Bapokutty. *Fatigue life behaviour of fibreglass reinforced composites subjected to constant amplitude loadings*. Postgraduate Research Symposium In Mechanical Engineering 2017 (PRISME), Melaka, 5 January 2017.
- 5     K. A. Zakaria, R.H. Jimit, S.N.S. Ramli, A.A. Azizi, O. Bapokutty and M. B. Ali, 2016. *Study on Fatigue life and fracture behaviour of fiberglass-reinforced composites*. The 4<sup>th</sup> International Conference on Engineering & ICT 2016 (ICEI), Melaka, 4-6 April 2016.
- 6     R. H. Jimit, K.A. Zakaria and O. Bapokutty. *Fatigue life behaviour of fibreglass reinforced composites subjected to variable amplitude loadings*. Postgraduate

Research Symposium In Mechanical Engineering 2016 (PRISME), Melaka, 5  
January 2016.

## CHAPTER 1

### INTRODUCTION

#### 1.1 Background of Study

Recently, public awareness on the environment and safety issues is continuously increasing throughout the world. Environmental problems such as air pollution and water pollution have become a serious problem not only in developed country but also developing country. This problem can endanger animals, plants as well as deteriorate health of human beings. According to World Health Organization (WHO), almost seven million people worldwide died in year 2012 due to air pollution (WHO, 2014). Combustion of vehicle fuel had been identified as the main factor which causes air pollution. EU has set the aim to decrease the emissions with 20 % compared to today to 2020 (Scania AB, 2011). One way to reduce fuel consumption is weight reduction of the body structure of vehicle. Therefore, the applications of composite material become an interest and hot topic among the researcher and public as it can reduce vehicle weight.

Composite consists of two or more microscopically combined materials to produce a new and better quality material. From the production of composite , the mechanical properties of the material such as strength, stiffness, corrosion resistance, wear resistance, fatigue strength, temperature-dependent behaviour and thermal conductivity can be improved (Banakar et al., 2012; Mukul and Sachin, 2012 cited in Banakar et al., 2017). One of the most significant type of composite is fiber-reinforced composite (FRC) that mostly used as an engineering structure and component in industrial. FRC consists of fibers of high strength and modulus embedded in or bonded to a matrix with boundaries between them. In this form, both fibers and matrix resin maintain their physical and